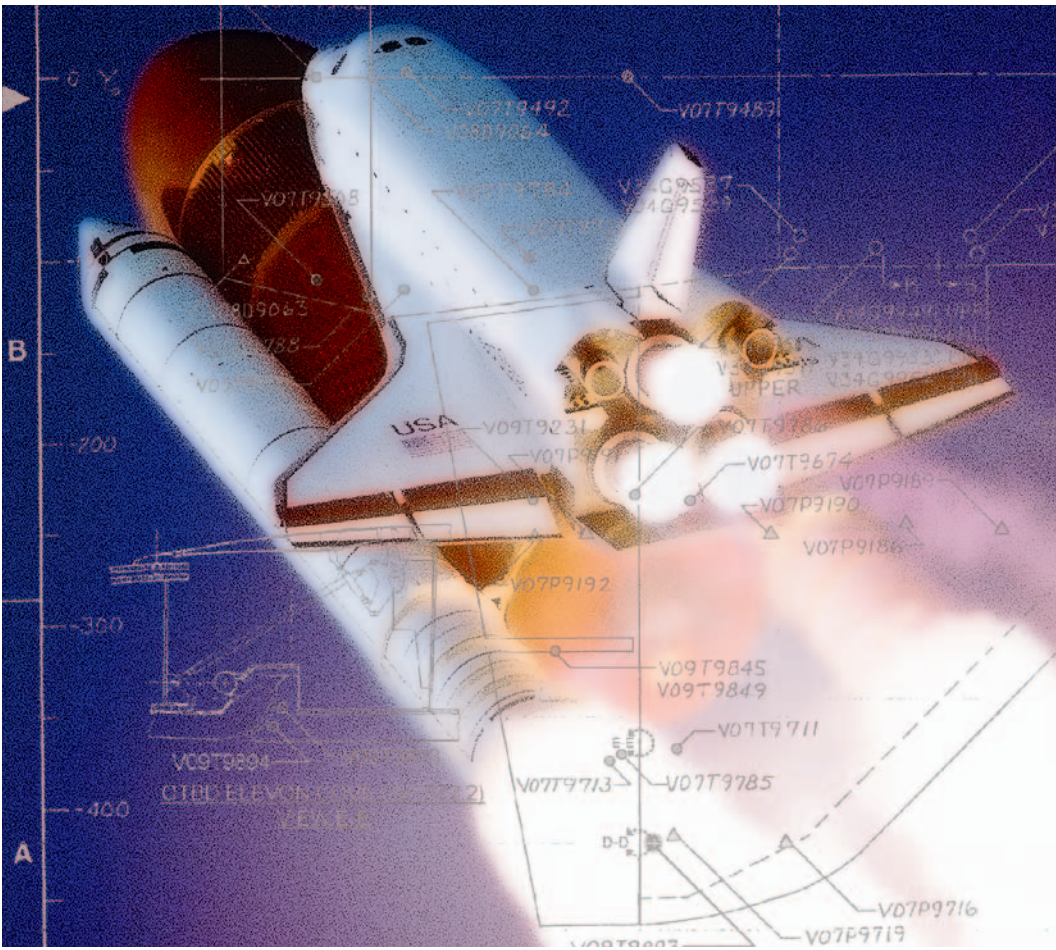
National Aeronautics and
Space Administration

THE ROLE OF

Small Businesses

IN NASA'S RETURN TO FLIGHT INITIATIVE



Office of Small and Disadvantaged Business Utilization
April 2005

OSDBU Strategic Mission:

To provide expertise on the utilization of innovative small businesses that can deliver technical solutions in support of the NASA mission.

NASA fuels discoveries that make the world smarter, safer, and healthier. As evident throughout this publication, small businesses are significantly contributing to a safe return to flight, and as the Shuttle reaches full flight status, small businesses will be there with innovative technology to ensure the success of the mission and the safety and health of the crew.

Foreword

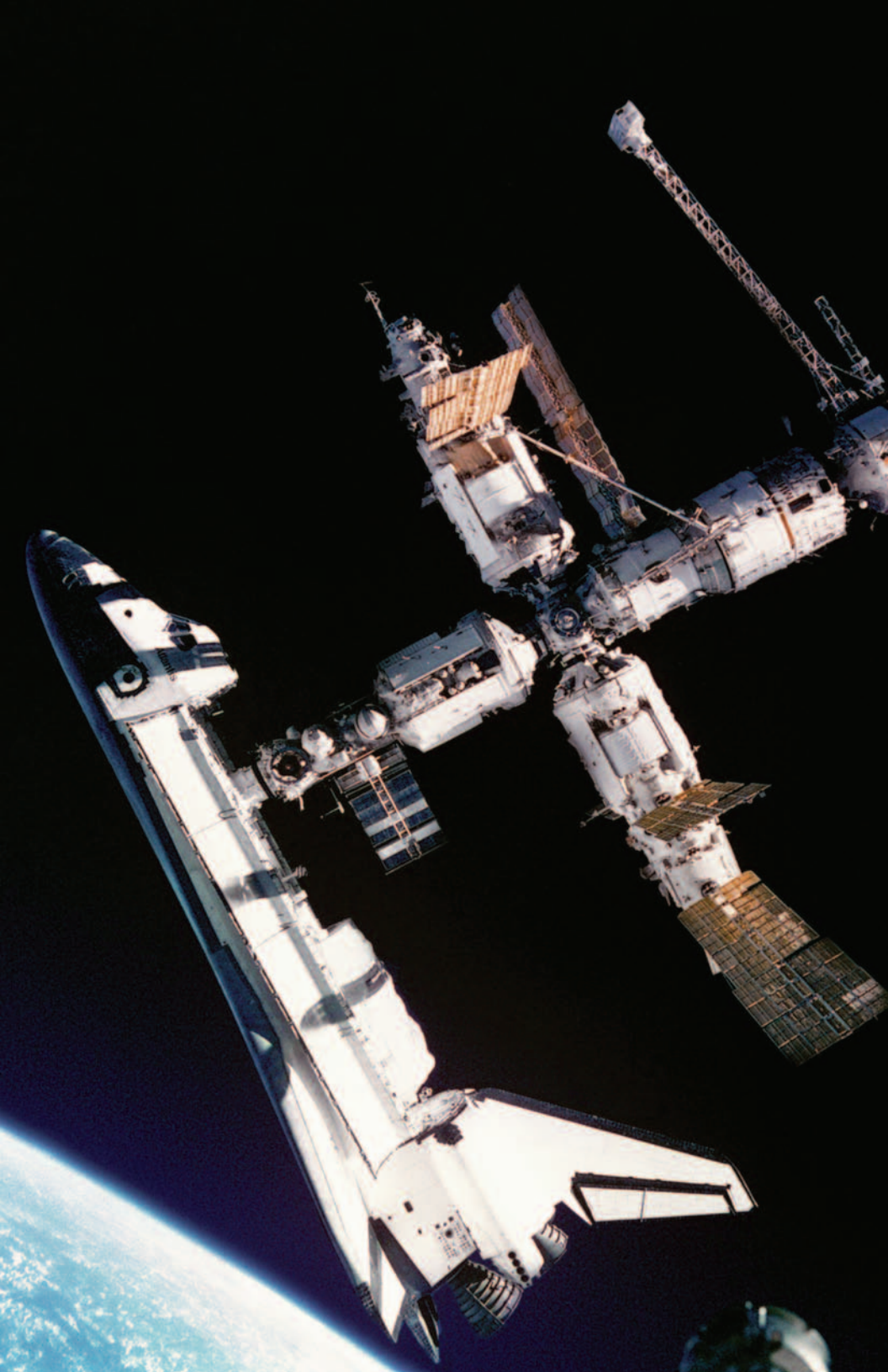
A Statement from Mr. Ralph C. Thomas III, Assistant Administrator for Small and Disadvantaged Business Utilization

The purpose of this publication is to showcase the role of small businesses in accomplishing the first priority of NASA's New Vision for Space Exploration—the return to safe flight. I'm happy to say that small businesses, including small, disadvantaged, and women-owned firms, are among the many entities that are helping us to carry out this effort. Other small businesses, such as veteran-owned companies, service disabled veteran-owned firms, and Historically Underutilized Business (HUB) Zone contractors, have been instrumental in this effort as well. Our Return to Flight (RTF) activities are primarily dictated by the Columbia Accident Investigation Board (CAIB) Report. The CAIB Report contains a series of recommendations designed to help the Agency return to safe flight. Small businesses are directly engaged in contracts and subcontracts to assist NASA in following those recommendations.

The primary objective of the Office of Small and Disadvantaged Business Utilization (OSDBU) is to prepare and identify small businesses that can provide technical solutions to NASA's most high-tech space missions. The pages that follow reflect examples of our successes in doing so by illustrations of small businesses making significant contributions to the Return to Flight Initiative. Their outstanding efforts will help to ensure that NASA will achieve its goal and return to safe flight in 2005. These small businesses will be providing support right through the completion of this initiative. This is being made possible through their full integration into the core priorities of the Agency as a whole.

On behalf of NASA, I want to commend the small business community for performing excellent work in such a critical area. It is important to stress that no allowances are made to any firm for anything less than the best in safety and quality assurance. We are pleased that the small businesses working on this initiative are meeting that standard of excellence, as is evidenced in the pages of this publication.

NASA is indeed thankful for the continued dedication and support of small businesses in helping NASA achieve its important goal of returning to safe flight and to NASA's technical, procurement, and program managers who gave them the opportunity.



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PART ONE—THE ACCIDENT

THERMAL PROTECTION SYSTEM

The Thermal Protection System (TPS) is comprised of various materials applied externally to the outer structural skin of the orbiter to maintain the skin within acceptable temperatures, primarily during the entry phase of the mission. The orbiter's outer structural skin is constructed primarily of aluminum and graphite epoxy. During entry, the TPS materials protect the orbiter's outer skin from temperatures above 350 degrees Fahrenheit. These materials protect the orbiter in conditions that range in temperature from minus 250 degrees Fahrenheit in the cold soak of dark space to entry temperatures that reach nearly 3,000 degrees Fahrenheit.

The CAIB Report found that the physical cause of the loss of Columbia and its crew was a breach in the Thermal Protection System on the leading edge of the left wing, caused by a piece of insulating foam which separated from the left bipod ramp section of the External Tank at 81.7 seconds after launch, and struck the wing in the vicinity of the lower half of Reinforced Carbon-Carbon panel number 8.

The work described below is to correct this problem and ensure the safety of future flights.The cited CAIB recommendations are included verbatim in the back of this publication

AMES RESEARCH CENTER

Contractor: Bay Systems, Oakland, CA

Classification: Woman-Owned Small Business

Jasmine Ali, President/CEO

This firm, headed by Ms. Jasmine Ali, is providing support services for aerospace testing and facilities maintenance and operations for wind tunnels and the thermophysics testing complex. The company is also managing and administering the technical staff in the Unitary Plan Wind Tunnel Facility. The work is being performed as a subcontract to Jacobs/Sverdrup, a large company based in Tullahoma, TN.

AMES RESEARCH CENTER

Contractor: ASRC Aerospace Corp., Greenbelt, MD

Classification: Small Native Alaskan Corporation

This firm provides design and drafting support for the orbiter's nose and wing pressure tap installation, RSRB joint ring design/installation, model support hardware, model installation and model protuberance detail designs in support of CAIB #R3.3-2.

AMES RESEARCH CENTER

Contractor: AMTI, Rosslyn, VA
Classification: Woman-Owned Small Business

This company is providing services with regard to grid systems engineering and high-end computing operations in support of CAIB #R3.2-1.

AMES RESEARCH CENTER

Contractor: Sierra Lobo, Inc., Fremont, OH
Classification: Small Disadvantaged Business

Sierra Lobo tests foam insulation and new materials in support of RTF activities; in particular, they support CAIB #R3.2-1 and R6.4-1. Several candidate materials for the Shuttle External Tank foam were recently tested at the Aerodynamic Heating Facility, the purpose of which is to eliminate the shedding of External Tank foam. Also, the test series in support of the development of the leading edge "repair kit" for the Shuttle astronauts was just completed at the Interaction Heating Facility.

AMES RESEARCH CENTER

Contractor: Eloret Corp., Sunnyvale, CA
Classification: Small Business

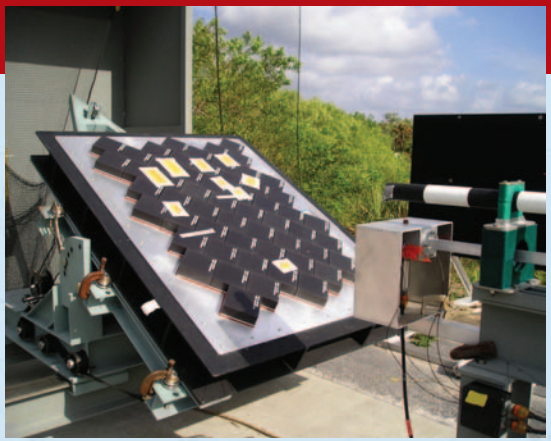
This firm is defining foam trajectories for pieces of debris coming off the external tanks using CART3D enhancements. The work supports CAIB #R3.2-1.

Eloret also provides science and engineering support in space technology, which supports CAIB #R3.2-1; R3.3-2; R6.4-1.

AMES RESEARCH CENTER

Contractor: AerospaceComputing, Inc. (ACI), Mountain View, CA
Classification: Small Disadvantaged Business

The ACI team was responsible for the aero-acoustic portion of the 3 percent Space Shuttle test conducted at Ames and at Arnold Engineering and Development Center (AEDC) in Tullahoma, TN. The test was conducted to characterize the unsteady pressure loads induced on the new External Tank (ET) bipod strut configuration. The AEDC test presented unique challenges because of the distance from the model to the control room. To meet the challenge, the team designed and built a 32-channel amplifier system small enough to be located in the model. This test supports CAIB #R3.2-1.



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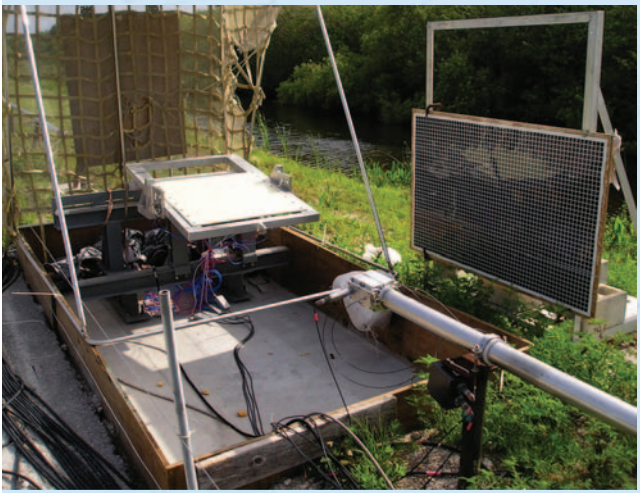

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1 *Shuttle TPS testing panel for ablator impact testing.*

2 *Ablator projectile systems for characterizing impact velocity up to 2,000 ft/sec.*

3 *Sample instrumentation configuration for IPSS.*

4 *Test configuration for IPSS.*

5 *Aero-acoustic test model of the Shuttle Launch Configuration for the External Tank Bipod Strut configuration study. Image was captured at Ames 9- by 7-ft Supersonic Test Facility.*

GLENN RESEARCH CENTER

Contractor: QSS, Inc., Lanham, MD
Classification: Small Disadvantaged Business

QSS and its two small business subcontractors are providing a wide range of research and development to aid in the Return to Flight efforts. Its contract employees have developed the Glenn Adhesive Refractory for Bonding and Exterior Repair (GARBER) material. This material is being considered for use as an on-orbit crack repair for damaged Shuttle heat shields. Successful tests have been performed while flying in the KC-135 to evaluate the crack filling and troweling behavior under microgravity conditions. Samples were taken to NASA Ames and were subjected to a high temperature arc jet for 15 minutes, simulating the Shuttle reentry profile. All samples successfully survived the tests without any burn-through.

KENNEDY SPACE CENTER

Contractor: ASRC Aerospace Corp., Greenbelt, MD
Classification: Small Native Alaskan Corporation

ASRC is involved in the following activities:
Impact Penetration Sensor System for RCC and L1900 Tile—Developing a Non Destructive Evaluation (NDE) sensor system to identify impact energy levels above and below damage thresholds on orbiter Reinforced Carbon-Carbon and High-Temperature Reusable Surface Insulation (HRSI) tile.

NDE Support in Preparation for RTF—Providing technical expertise for NDE activities supporting RTF. Main tasks are to provide an assessment of current technologies that can be used for NDE of the orbiter's Leading Edge Sub System and External Tank foam.

Ablator Impact Testing—Providing ablator impact testing to determine the amount of damage caused to the Shuttle Thermal Protection System (TPS) by various sizes of ablator Foreign Object Damage (FOD).

LANGLEY RESEARCH CENTER

Contractor: Materials Research & Design, Inc., Wayne, PA
Classification: Small Business

This firm is providing engineering, development, and fabrication of carbon-silicon carbide (C-SiC) wrap components to enable an on-orbit repair capability for Space Shuttle mission STS-114 and subsequent missions.

LANGLEY RESEARCH CENTER

Contractor: Digital Wave Co. (DWC), Englewood, CO
Classification: Small Business

This firm is performing the following tests:
Technical support for Acoustic Emission Testing—Performing support of foam impact testing of Shuttle components at Southwest Research Institute.

Technical Support for Acoustic Emission Testing—Conducting additional effort to analyze the effects of the Spray On Foam Insulation projectiles against the Reinforced Carbon protective wrap on the leading edge of the orbiter.

Developing sensor broadband and sensor cables for DWC data acquisition system used for impact tests.

Performing the repair of preamp instruments.

Working on the 16-channel Acoustic Emission Monitoring System in support of foam impact testing.

Working on the Very Low Frequency Ultrasonic Analyzer in support of acoustic emission-based measurements of Shuttle foam impacts.

Providing consultant support for Impact Testing.

LANGLEY RESEARCH CENTER

Contractor: Picometrix, Ann Arbor, MI
Classification: Small Business

Picometrix's work involves:
Tetrahertz Imaging System—This system is to be used for evaluating the Spray On Foam Insulation attachment at the External Tank Bipod Region.

Replacing fiber optic cable assemblies.

LANGLEY RESEARCH CENTER

Contractor: Detek, Temple Hills, MD
Classification: Veteran-Owned Small Business

This firm is developing the Flash Portable Digital Radiography System with Computer Data Acquisition for non-destructive testing of Reinforced Carbon-Carbon. It is also performing work on the Eddy Current Test Equipment with regard to Return to Flight.

LANGLEY RESEARCH CENTER

Contractor: Jentek Sensors, Inc., Waltham, MA
Classification: Small Business

This firm is performing evaluation of Reinforced Carbon specimens.

LANGLEY RESEARCH CENTER

Contractor: Valador VA, Inc., Reston, VA
Classification: Service Disabled Veteran-Owned Small Business

This is a Blanket Purchase Agreement for ongoing services to the Return to Flight Task Group, including the provision of general, administrative, and expert services.

LANGLEY RESEARCH CENTER

Contractor: Advanced Technologies, Inc., Newport News, VA
Classification: Small Business

This firm performs design, analysis, and fabrication of the Sonic Orifice Model.

LANGLEY RESEARCH CENTER

Contractor: Thermal Wave Imaging (TWI), Inc., St. Ferndale, MI
Classification: Small Business

TWI is engaged in analyzing the Thermal Inspection System for Orbiter Leading Edge Reinforced Carbon-Carbon.

LANGLEY RESEARCH CENTER

Contractor: Swales Corporation, Bethesda, MD
Classification: Small Business

Swales provides Non Destructive Evaluation (NDE) support on multiple Notice of Revisions (NORs) including the following: Acoustic Emission, x ray, eddy current, Lamb wave, terhertz, and thermal imaging of spray on foam insulation (SOFI) and Reinforced Carbon-Carbon (RCC) materials to detect flaws/damage. This includes data acquisition, analysis, hardware and software development. The company is also developing concept design for the on-orbit repair of Shuttle Wing Leading Edge.

It is conducting the testing of adhesively bonded Honeycomb Core Sandwich specimens and a Simulated External Tank Helium Purge Test.

The firm is also helping the RTF effort by providing assistance with viewing and interpreting LO2 and LH2 tray modal data acquired at Marshall Space Flight Center.

Moreover, not only is Swales performing the analysis of Space Shuttle wing leading edge impacts, but it is also providing support to the Shuttle foam PAL (Protuberance Aerodynamic Load) Ramp Removal Study.

Most importantly, the company is engaged in conducting thermal structural analysis of on-orbit repair design, design and analysis for Shuttle wing internal jet impingement model, and damage study of orbiter flowliner, and is performing metals cleaning, corrosion, and metallurgical analysis support on multiple Notice of Revisions.

Finally, Swales is involved in the processing of Change Reports (CR)-MgO alloys via plasma spray and vacuum hot press.

JOHNSON SPACE CENTER

Contractor: Hernandez Engineering, Inc. (HEI), Houston, TX
Classification: Woman-Owned Small Business

Tery Hernandez, CEO

HEI's work on the Position Orientation Hold Submode (POHS) in Autosequence Team allowed the Shuttle Remote Manipulator System (SRMS) to more accurately track a desired trajectory and added safety features that will stop SRMS motion should a failure occur. This work supports CAIB #R6.4-1.

Meanwhile, the company is also performing thermal analysis, design, safety analysis, and system engineering for the Cure In Place Ablator Applicator (CIPAA). This is the repair material for the Thermal Protection System.This work supports CAIB #R6.4-11.

With regard to Thermal Protection System (TPS) material testing, evaluation, and database development, HEI personnel are performing acquisition and photogrammetry-based analysis of high-speed movies collected during impact testing of TPS materials. In this regard, HEI provided NASA with high precision material ballistics and deflection results. A TPS-impact movie database is being populated with movie location and description information, as well as imaging hardware settings. HEI personnel are also involved in logistics and setup operations in support of the impact testing, principally at Southwest Research Institute in San Antonio, TX in compliance with CAIB #R3.3-4.

MARSHALL SPACE FLIGHT CENTER

Contractor: Hernandez Engineering, Inc (HEI), Houston, TX
Classification: Woman-Owned Small Business

HEI is supporting the ET Bipod Redesign with Safety, Reliability and Quality and is also supporting a statistical determination for probability of foam shedding for the refined foam application process. This work addresses CAIB #3.2-1.

HEI is also providing Safety, Reliability and Quality support to a materials development task force; the selected material will be used for possible on-orbit panel crack repair.

This is a photo of the low pressure gas gun (chicken gun) and a Shuttle wing leading edge panel. The gun fires a piece of the ET foam insulation to simulate the accident that brought down the Columbia. Notice the high-speed digital video cameras and lighting used to record the impact to the wing. HEI engineers were tasked to analyze the 3-D kinematics of the impact.

LANGLEY RESEARCH CENTER

Contractor: AerospaceComputing, Inc. (ACI), Mountain View, CA
Classification: Small Disadvantaged Business

Hiro Kumagai, President

ACI has assisted NASA's effort in the development of an experimental heating database to determine Shuttle orbiter tile damage thresholds that could trigger corrective action such as on-orbit repair of thermal protection system tiles. This work is paramount to CAIB #R3.3-3.

Additionally, ACI assisted NASA in the development of the experimental database to determine repair criteria to protect the Shuttle orbiter from elevated structural temperatures resulting from disturbances in airflow created by thermal protection system damage and/or repairs. This work is in compliance with CAIB #R3.8-2.

IMAGING

KENNEDY SPACE CENTER

Contractor: ASRC Aerospace Corp., Greenbelt, MD
Classification: Small Native Alaskan Corporation

This company supported the Return to Flight Ground Camera Project by providing project management and engineering support to the NASA-led project.

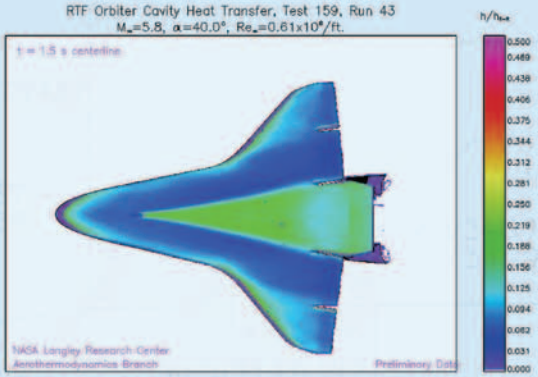
The project's objective is to upgrade existing imaging systems to provide the capability of having a minimum of three useful views of the Space Shuttle from lift-off to SRB separation.

MICROMETEOROID & ORBITAL DEBRIS

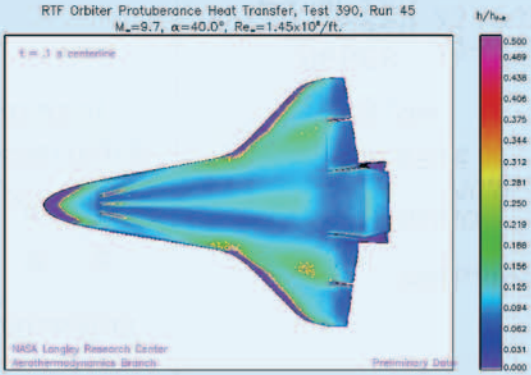
GLENN RESEARCH CENTER

Contractor: Ares Corp., Burlingame, CA
Classification: Small Business

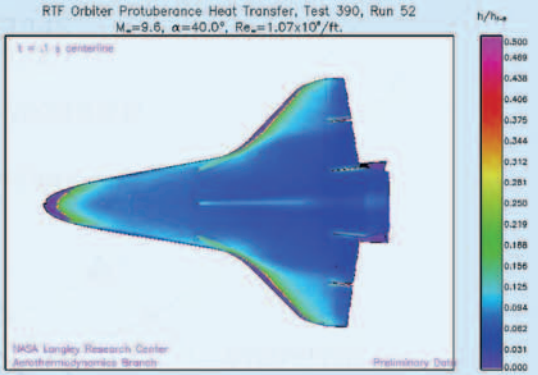
The company is managing the highly secure network and applications used by the Columbia Task Force to catalog and analyze the debris and debris field of Columbia.



Heat transfer image of Shuttle orbiter showing cavity damage. Image was captured using the Phosphor Thermographic Method at Langley 20-Inch Mach 6 CF4 Facility.



Heat transfer image of Shuttle orbiter showing protuberance effects. Image was captured using the Phosphor Thermographic Method at Langley 31-Inch Mach 10 Air Facility.



Heat transfer image of Shuttle orbiter showing protuberance effects. Image was captured using the Phosphor Thermographic Method at Langley 31-Inch Mach 10 Air Facility.

ORBITER SENSOR DATA

DRYDEN FLIGHT RESEARCH CENTER

Contractor: Invocon, Inc., Conroe, TX
Classification: Veteran-Owned Small Business

Invocon, Inc. developed the Flight Wing Leading Edge Impact Detection System. The firm developed a wireless data acquisition and communications system for monitoring the Shuttle Wing Leading Edge RCC panels during ascent and on-orbit phases for potentially damaging impacts from foam, ice, ablator, and metallic objects. The 132-channel accelerometer-based system is being installed within the Shuttle wings for the Return to Flight mission, STS-114, and subsequent missions to assist in detecting, locating, and characterizing the severity of impact events similar to the debris impact that caused the Columbia disaster. Resulting data from this system will be used to assist in determining likely impact locations requiring further inspections on-orbit. Each battery-operated unit interfaces with high-speed accelerometers and temperature sensors, records data internally, performs detection algorithms, and transfers data through Shuttle systems for analysis by ground personnel.

The company also provided support to the foam impact testing of RCC panels at Southwest Research Institute (SWRI) and provided data acquisition hardware and engineering support during impact testing of RCC panels at Southwest Research Institute. Invocon has assisted in the instrumentation of test articles, operation of the instrumentation during impact tests, analysis of acquired data, and development of data processing algorithms for impact detection on-orbit.

Moreover, Invocon performed a study of the Impact Penetration Sensor System on the effect of reducing the size and power requirements of the next generation system for monitoring critical areas of the Shuttle structure for impacts.

JOHNSON SPACE CENTER

Contractor: Hernandez Engineering, Inc. (HEI), Houston, TX
Classification: Woman-Owned Small Business

This company is instrumental in providing an independent calibration of an acceleration measurement device used to assess the magnitude of accelerations experienced by Columbia during her tragic reentry. CAIB #R3.6-1; R3.6-2.


Columbia
United States

PART TWO—WHY THE ACCIDENT OCCURRED

SCHEDULING

The CAIB's Report findings were that the organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed upon national vision for human space flight.

LANGLEY RESEARCH CENTER
Contractor: Swales, Bethesda, MD
Classification: Small Business

Swales is working on Programs/Projects Schedules Management and Reporting.

ORGANIZATION

KENNEDY SPACE CENTER
Contractor: ASRC Aerospace Corp., Greenbelt, MD
Classification: Small Native Alaskan Corporation

This firm provides project management and technical support to the RTF Shuttle Engineering Team (PH).

MARSHALL SPACE FLIGHT CENTER

Contractor: Hernandez Engineering, Inc. (HEI), Houston, TX
Classification: Woman-Owned Small Business

The System Safety Engineering group attended and participated in the RTF Pre-Board meeting on Instrumenting the External Tank (ET) Cable Trays representing the Safety and Mission Assurance position for the need of instrumentation of the Cable Trays. HEI is also working to generate a coordinated response to the Independent Assessment questionnaire for the External Tank project on methodology and closure of review board RTF directive for review of accepted risk hazard report and applicable Critical Items Lists (CILs).

The SSME Quality Engineering group participated in the investigation of contamination discovered on OV-104 Orbiter Main Propulsion System. Contamination was found at the pre-valve screen and was recurring with each inspection. HEI's SSME Quality Engineering group worked with MSFC and JSC personnel to develop a system logic probability study quantifying the risk to the engine due to a worst-case contamination environment. HEI engineers also continued to support the flowliner crack investigation and test program.

In support of the Shuttle Assurance Department, HEI's Reliability and Maintainability Engineering (R&ME) group is actively involved in RTF activities for all of the propulsion elements, including review and update of CIL retention rationale and accepted risk hazard reports. The R&ME group is participating in the ET RTF effort for the Feedline Bellows redesign and Enhanced Launch Vehicle Imaging System, and made numerous trips to the Michoud Assembly Facility to participate in team meetings, reviews, and test activities associated with these redesign efforts. In addition to the ongoing efforts related to Shuttle upgrades, HEI actively participated in the qualification process for the SRB Integrated Electronics Assembly (IEA) wire harness upgrade. R&ME participated as a member of a team that went to Labarge, manufacturer of the IEA wire harnesses, to review and approve critical processes and procedures that are used in the IEA harness replacement upgrade. The R&ME group participated in the Reusable Solid Rocket Motor (RSRM) Propellant Grain Redesign Preliminary Design Review (PDR) and Nozzle Joint 2 Carbon Fiber Rope Critical Design Review (CDR), and reviewed Thiokol's System Safety/Reliability assessment and methodology to determine the risks, hazards, and failures associated with the design, hardware and process changes. The R&ME supervisor was designated by Marshall Space Flight Center's (MSFC) Department of Quality QS20 to serve as the MSFC focal for the newly established Space Shuttle Reliability & Maintainability (R&M) Panel. This panel has been chartered to assure the implementation of the SSP R&M programmatic and technical requirements across all Shuttle program elements.

LANGLEY RESEARCH CENTER

Contractor: Futron, Bethesda, MD
Classification: Small Disadvantaged Business

Joe Fuller
President/CEO

Futron is developing a Draft NASA Policy Regulation (NPR), tentatively entitled "Program Health Management." This Draft NPR has a trend analysis focus; however, it is written such that it will immediately be a companion document to NPR 8000.4 "Risk Management Procedures and Guidelines." The ultimate goal is to combine the two NPRs into one document.

The firm is also developing a prototype 'war room' under the direction of the NASA Engineering and Safety Center (NESC) Deputy Director of Systems Engineering. This war room is collecting existing data from the three flight centers (MSFC, JSC, KSC) to determine: what information is currently being collected, current trend analysis practices being used, and what information should be, but is not currently, collected and/or reported.

Through the NESC Safety and Mission Assurance (SMA) Board, Futron is responsible for collecting significant problems from each member. This collection is documented in the ***Significant Problems Report***, which is uploaded to the NESC SMA Board Process Based Mission Assurance Web site for all SMA Board members to view and provide comments.

Anomalies suspected during Futron's in-depth analysis of the data is provided to the NESC Deputy Director of Systems Engineering for the current Recurring Anomalies Study being conducted.

Futron has been informed that it is likely that the Pre-Launch Assessment Review (PARs) will be added to the contract. This will support the verification of launch readiness. However, at this time, as a result of no flight, a PARs does not exist.


USA

PART THREE—A LOOK AHEAD

ORGANIZATION

This section focuses on continuing-to-fly recommendations, since they capture the Board's thinking on the changes necessary to safely operate the Shuttle and future spacecraft.

LANGLEY RESEARCH CENTER

Contractor: Futron, Bethesda, MD
Classification: Small Disadvantaged Business

Futron provided contract support to the NESC in December 2003 by tailoring Futron's Integrated Risk Management Application (IRMA) into the NASA Engineering and Safety Center (NESC) Assessment Risk Management Application (NARMA) tool. This tool not only provides a tracking and communication capability, but was used during this effort to investigate and report, for comparison purposes, risk tolerance levels of other industries, other modes of transportation, and other life-threatening events.


NASA

PART FOUR—RECOMMENDATIONS

COLUMBIA ACCIDENT INVESTIGATION BOARD (CAIB) RECOMMENDATIONS

It is the Board's opinion that good leadership can direct a culture to adapt to new realities. NASA's culture must change, and the Board intends the following recommendations to be steps toward effecting this change.

The recommendations are grouped by subject area with the Return-to-Flight [RTF] tasks listed first within the subject area. Each Recommendation retains its number so the reader can refer to the related section [in the Board's report] for additional details. These recommendations are not listed in priority order.

PART ONE—THE ACCIDENT

Thermal Protection System

R3.2-1 Initiate an aggressive program to eliminate all External Tank Thermal Protection System debris-shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank. [RTF]

R3.3-2 Initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced Carbon-Carbon and acreage tiles. This program should determine the actual impact resistance of current materials and the effect of likely debris strikes. [RTF]

R3.3-1 Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology. [RTF]

R6.4-1 For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities available when near to or docked at the International Space Station.

For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.

Accomplish an on-orbit Thermal Protection System inspection, using appropriate assets and capabilities, early in all missions.

The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking. [RTF]

R3.3-3 To the extent possible, increase the Orbiter's ability to successfully re-enter Earth's atmosphere with minor leading edge structural sub-system damage.

R3.3-4 In order to understand the true material characteristics of Reinforced Carbon-Carbon components, develop a comprehensive database of flown Reinforced Carbon-Carbon material characteristics by destructive testing and evaluation.

R3.3-5 Improve the maintenance of launch pad structures to minimize the leaching of zinc primer onto Reinforced Carbon-Carbon components.

R3.8-1 Obtain sufficient spare Reinforced Carbon-Carbon panel assemblies and associated support components to ensure that decisions on Reinforced Carbon-Carbon maintenance are made on the basis of component specifications, free of external pressures relating to schedules, costs, or other considerations.

R3.8-2 Develop, validate, and maintain physics-based computer models to evaluate Thermal Protection System damage from debris impacts. These tools should provide realistic and timely estimates of any impact damage from possible debris from any source that may ultimately impact the Orbiter. Establish impact damage thresholds that trigger responsive corrective action, such as on-orbit inspection and repair, when indicated.

Imaging

R3.4-1 Upgrade the imaging system to be capable of providing a minimum of three useful views of the Space Shuttle from liftoff to at least Solid Rocket Booster separation, along any expected ascent azimuth. The operational status of these assets should be included in the Launch Commit Criteria for future launches. Consider using ships or aircraft to provide additional views of the Shuttle during ascent. [RTF]

R3.4-2 Provide a capability to obtain and downlink high-resolution images of the External Tank after it separates. [RTF]

R3.4-3 Provide a capability to obtain and downlink high-resolution images of the underside of the Orbiter wing leading edge and forward section of both wings' Thermal Protection System. [RTF]

R6.3-2 Modify the Memorandum of Agreement with the National Imagery and Mapping Agency to make the imaging of each Shuttle flight while on orbit a standard requirement. [RTF]

Orbiter Sensor Data

R3.6-1 The Modular Auxiliary Data System instrumentation and sensor suite on each Orbiter should be maintained and updated to include current sensor and data acquisition technologies.

R3.6-2 The Modular Auxiliary Data System should be redesigned to include engineering performance and vehicle health information, and have the ability to be reconfigured during flight in order to allow certain data to be recorded, telemetered, or both as needs change.

Wiring

R4.2-2 As part of the Shuttle Service Life Extension Program and potential 40-year service life, develop a state-of-the-art means to inspect all Orbiter wiring, including that which is inaccessible.

Bolt Catchers

R4.2-1 Test and qualify the flight hardware bolt catchers. [RTF]

Closeouts

R4.2-3 Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures. [RTF]

Micrometeoroid and Orbital Debris

R4.2-4 Require the Space Shuttle to be operated with the same degree of safety for micrometeoroid and orbital debris as the degree of safety calculated for the International Space Station. Change the micrometeoroid and orbital debris safety criteria from guidelines to requirements.

Foreign Object Debris

R4.2-5 Kennedy Space Center Quality Assurance and United Space Alliance must return to the straightforward, industry-standard definition of "Foreign Object Debris" and eliminate any alternate or statistically deceptive definitions like "processing debris." [RTF]

PART TWO—WHY THE ACCIDENT OCCURRED

Scheduling

R6.2-1 Adopt and maintain a Shuttle flight schedule that is consistent with available resources. Although schedule deadlines are an important management tool, those deadlines must be regularly evaluated to ensure that any additional risk incurred to meet the schedule is recognized, understood, and acceptable. [RTF]

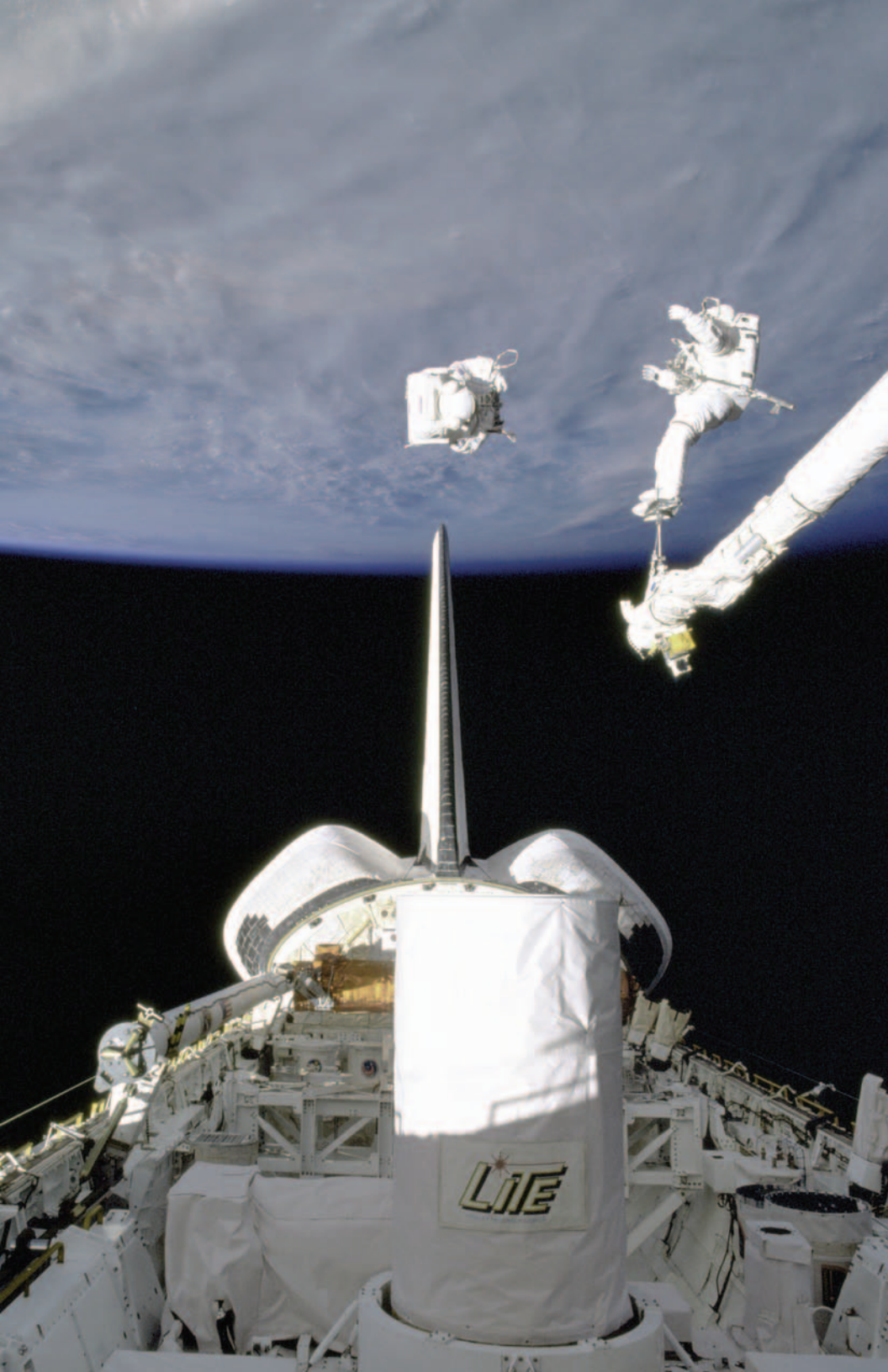
Training

R6.3-1 Implement an expanded training program in which the Mission Management Team faces potential crew and vehicle safety contingencies beyond launch and ascent. These contingencies should involve potential loss of Shuttle or crew, contain numerous uncertainties and unknowns, and require the Mission Management Team to assemble and interact with support organizations across NASA/Contractor lines and in various locations. [RTF]

Organization

R7.5-1 Establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System. The independent technical authority does the following as a minimum:

- Develop and maintain technical standards for all Space Shuttle Program projects and elements
- Be the sole waiver-granting authority for all technical standards.
- Conduct trend and risk analysis at the sub-system, system, and enterprise levels
- Own the failure mode, effects analysis and hazard reporting systems
- Conduct integrated hazard analysis
- Decide what is and is not an anomalous event
- Independently verify launch readiness
- Approve the provisions of the recertification program called for in Recommendation R9.1-1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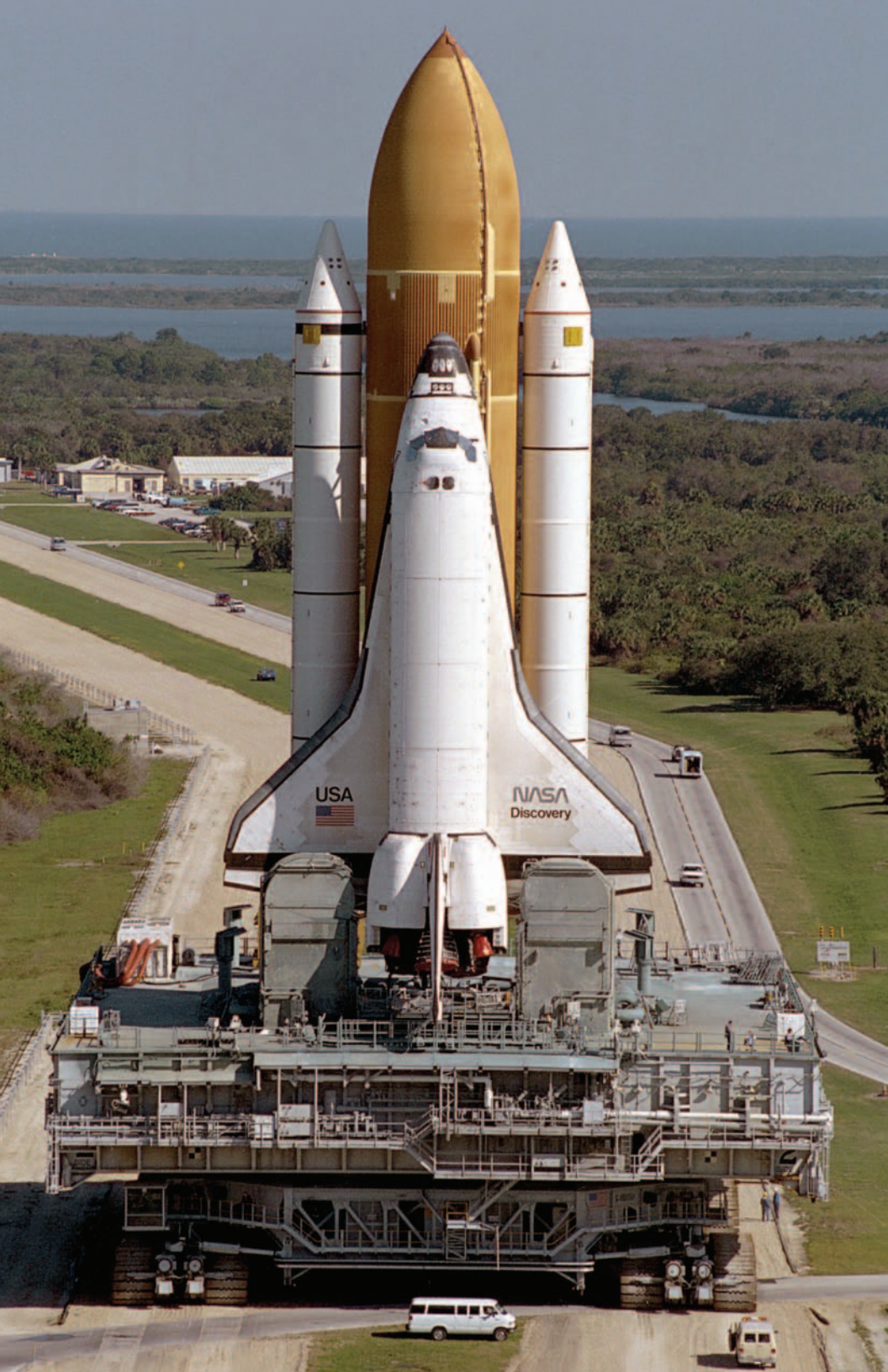
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. The Technical Engineering Authority should be funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost.

R7.5-2 NASA Headquarters Office of Safety and Mission Assurance should have direct line authority over the entire Space Shuttle Program safety organization and should be independently resourced.

R7.5-3 Reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Orbiter.

PART THREE—A LOOK AHEAD

Organization

R9.1-1 Prepare a detailed plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office as described in R7.5-1, R7.5-2, and R7.5-3. In addition, NASA should submit annual reports to Congress, as part of the budget review process, on its implementation activities. [RTF]

Recertification

R9.2-1 Prior to operating the Shuttle beyond 2010, develop and conduct a vehicle recertification at the material, component, subsystem, and system levels. Recertification requirements should be included in the Service Life Extension Program.

Closeout Photos/Drawing System

R10.3-1 Develop an interim program of closeout photographs for all critical sub-systems that differ from engineering drawings. Digitize the closeout photograph system so that images are immediately available for on-orbit troubleshooting. [RTF]

R10.3-2 Provide adequate resources for a long-term program to upgrade the Shuttle engineering drawing system including:

- Reviewing drawings for accuracy
- Converting all drawings to a computer-aided drafting system
- Incorporating engineering changes

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To extend life to there,
To find life beyond.

The NASA Mission

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To explore the universe and search for life,
To inspire the next generation of explorers
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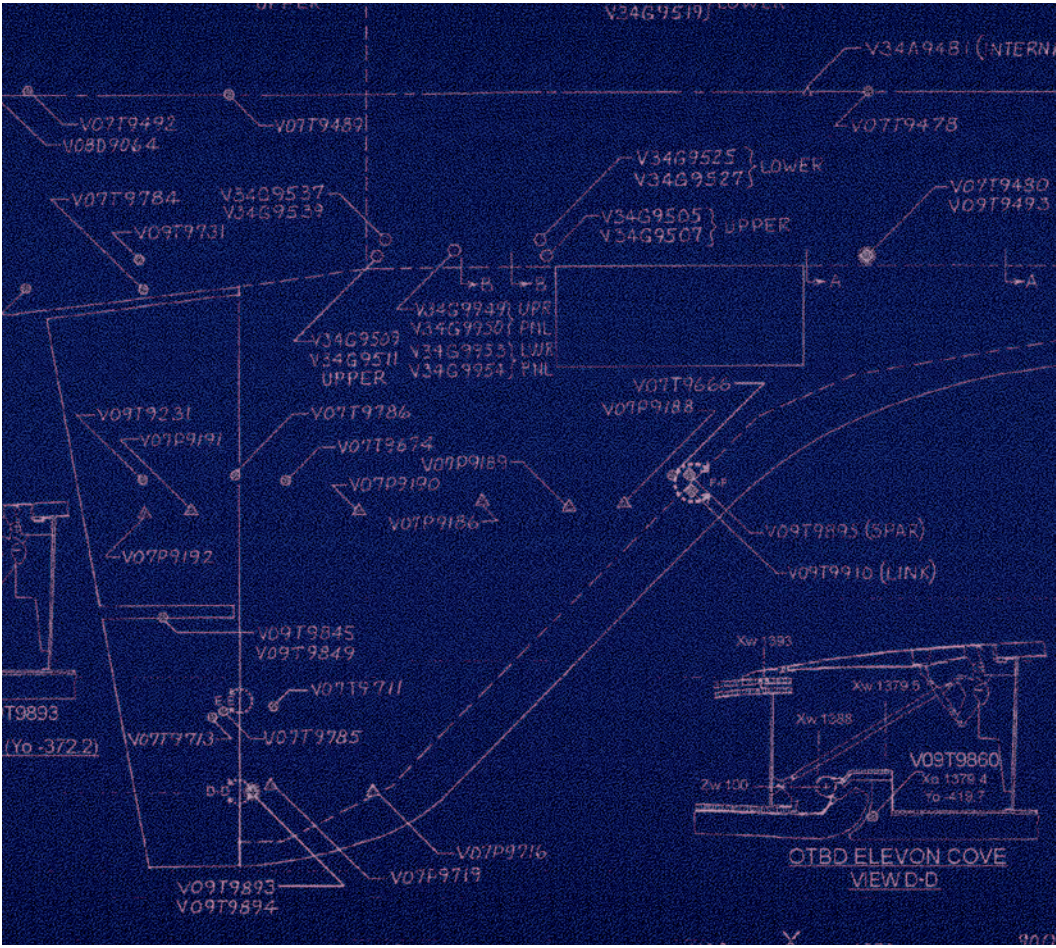

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